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(57) [Abstract]

[Problem] To reduce stress on a switch without increasing the number of components in a power element.

[Solution] A power source device comprising a full-wave rectifier DB, field-effect transistors (FETs) Q1, Q2, a load resonance circuit LD1, capacitors C11, C12, a smoothing capacitor CE10, an inductor L11 and diodes D11, D12, wherein the power source device further comprises a transformer CT 10 for detecting the regenerative current flowing via the FET Q1 side, a detection circuit 11 connected to the secondary coil n2 for detecting the magnetic saturation of the transformer CT10, an oscillation circuit 12 for generating a predetermined oscillation signal, and a drive circuit 13 for generating an ON/OFF drive signal using the oscillation signal from the oscillation circuit, operating the FETs Q1, Q2 using this drive signal and preventing the FETs Q1, Q2 from being turned on when magnetic saturation of the transformer CT10 is detected by the detection circuit 11.

[Claims]

[Claim 1] A power source device comprising a full-wave rectifier for performing full-wave rectification of alternating current voltage from an alternating current power source to direct current voltage, an inverter consisting of a series circuit having a load resonance circuit including an LC resonance circuit and a load and having a pair of switches, the inverter being connected to the output of the full-wave rectifier, a smoothing capacitor for supplying the direct current voltage to the inverter, a discharge diode for supplying direct current power from the smoothing capacitor to the inverter, a current transformer for detecting the regenerative current flowing via one of the pair of switches, and a charging diode for directing the charge current from the output of the full-wave rectifier to the smoothing capacitor via the other switch and the current transformer, wherein the other switch is prevented from turning on when the current transformer detects the regenerative current.

[Claim 2] The power source device of claim 1 further comprising a separately-excited control circuit for generating an oscillation signal and using this oscillation signal to generate a control signal for turning the switches on and off.

[Claim 3] The power source device of claim 1 further comprising a self-excited control circuit using the electromotive force induced by the drive coil magnetically connected to the current transformer to turn the switches to the inverter on and off, and wherein the current transformer is arranged in the route of the resonance current for the load resonance circuit.

[Claim 4] The power source device of claim 3, wherein the current transformer and the drive coil consist of a saturable transformer.

[Claim 5] The power source of any one of claims 1 through 3 further comprising an impedance element connected between the load resonance circuit and the output terminal of the full-wave rectifier.

[Claim 6] The power source device of any one of claims 1, 3 and 4 further comprising an impedance element connected in parallel to the current transformer.

[Claim 7] The power source device of any one of claims 1 and 3 through 5, wherein the current transformer is installed in one of the several routes for charging the smoothing capacitor.

[Claim 8] The power source device of any one of claims 1 and 3 through 5, wherein an inductor is installed to divide and output the charging current to the smoothing capacitor, and wherein the current transformer is installed in one of the divided routes of the inductor.

[Claim 9] A power source device comprising a full-wave rectifier for performing full-wave rectification of alternating current voltage from an alternating current power source to direct current voltage, an inverter including a series circuit with a pair of switches for converting the direct current voltage to high-frequency voltage, a smoothing capacitor for supplying direct current power to the inverter, a discharge diode for supplying direct current voltage from the smoothing capacitor to the inverter, a transformer in which the primary coil is inserted between the output terminal of the inverter and the direct current output terminal of the full-wave rectifier, a load resonance circuit including an LC resonance circuit and a load, an impedance element for connecting the load resonance circuit to the full-wave rectifier, and a current transformer for detecting the regenerative current generated via the other switch by the charging current flowing to the smoothing capacitor via the one switch and a portion of the load resonance circuit when the one switch among the pair of switches is turned on, wherein the one switch is prevented from turning on when the current transformer detects the regenerative current.

[Claim 10] A power source device comprising a full-wave rectifier for performing full-wave rectification of alternating current voltage to direct current voltage, a pair of switches connected in series between both output terminals of the full-wave rectifier, a direct current-preventing capacitor connected to one of the output terminals of the full-wave rectifier, a load resonance circuit consisting of an inductor, a capacitor including this inductor and an LC resonance circuit, and a load connected in parallel to this capacitor, the load resonance circuit being connected between the connection point for the pair of switches and the other terminal of the direct current-preventing capacitor, a smoothing capacitor connected to one of terminals to the pair of switches, a discharge diode connected to the other terminal to the pair of switches and the other terminal of the smoothing capacitor for directing flow of discharged current for the smoothing capacitor, a current transformer connected to the connection point for the pair of switches and one terminal of the primary coil for detecting the regenerative current flowing via the one switch, and a charging diode connected between the other terminal of the primary coil in the current transformer and the other terminal of the smoothing capacitor for directing the charging current of the smoothing capacitor when the other switch is turned on, wherein the other switch is prevented from turning on when the current transformer detects the regenerative current.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention] The present invention relates to a power source device for converting alternating current voltage from an alternating current power source to direct current voltage, converting the direct current voltage to high-frequency voltage, and supplying the high-frequency voltage to a load resonance circuit.

[0002]

[Prior Art] FIG 16 is a schematic diagram of a power source device of the prior art (disclosed in Japanese Unexamined Patent Application Publication No. JP9-98580A). This power source device comprises a full-wave rectifier DB for full-wave rectification of the alternating current voltage from an alternating current power source Vs to direct current voltage, FETs Q1, Q2 connected in series between the output terminals of the full-wave rectifier DB, an inductor L1 with one of the terminals connected to the positive output terminal of the full-wave rectifier DB, a smoothing capacitor C1 with the positive terminal connected to the other terminal of the inductor L1, a capacitor C2 connected in series between the source and drain of FET Q2, an inductor L2 and a load LD, a diode D1 connected between the source of FET Q2 and the negative terminal of the capacitor C1, a diode D2 connected between the negative terminal of the capacitor C1 and the connection point of FETs Q1 and Q2, and a capacitor C3 connected in parallel to the output side of the full-wave rectifier DB. In this configuration, a separately-excited control circuit not shown in the drawing is used to turn on and off FET Q1 and Q2.

[0003] The following is an explanation of the operation of a power source device with this configuration. When the power is turned on, FET Q2 is turned on and a large current flowing through a route consisting of alternating current power source Vs, full-wave rectifier DB, inductor L1, capacitor C1, diode D2, FET Q2, full-wave rectifier DB and alternating current power source Vs (route A) charges the capacitor C1. Afterwards, FET Q2 is turned off and a regenerative current flows through a route consisting of inductor L1, capacitor C1, diode D2, the parasitic diode of FET Q1 and inductor L1 (route B).

[0004] The regenerative current flows for a long time because the charge voltage of capacitor C1 is low. When FET Q2 is turned on again, the regenerative current is still flowing. As a result, FETs Q1 and Q2 are instantly shorted during the recovery period of the parasitic diode for FET Q1. The di/dt of both FETs increases, and a large amount of stress is applied to both FETs.

[0005] FIG 17 is a schematic diagram of a power source device of the prior art that solves this problem (disclosed in the same publication cited above). Unlike the power source device in FIG 16, this power source device is equipped with resistance R3 and FET Q3 connected in series to the source and drain of FET Q2, and a control circuit for turning on and off FETs Q1 through Q3.

[0006] This control circuit comprises a start circuit 1 for driving FET Q3, and a resonance circuit 2 for driving FETs Q1 and Q2 using the output signal from the start circuit 1.

[0007] The following is an explanation of the stress-reducing principles of this power source device. When the power is turned on, the start circuit 1 is activated and FET Q3 is turned on. The current used to charge capacitor C1 flows via a route consisting of alternating current power source Vs, full-wave rectifier DB, inductor L1, capacitor C1, diode D1, resistance R3, FET Q3, full-wave rectifier DB and alternating current power source Vs. This charges capacitor C1 and increases the charge voltage. Afterwards, the oscillation circuit 2 is activated and FET Q2 is turned on. The charging current flows through route A, and the time needed for the charging current is reduced by the prior charge. As a result, the so-called "simultaneous ON" problem is prevented.

[0008]

[Problem Solved by the Invention] However, the power source device of the prior art shown in FIG 17 requires resistance R1, a power element (FET Q3) and a start circuit 1-to drive FET Q3.

[0009] In light of this situation, the purpose of the present invention is to provide a power source device able to reduce the stress on a switch without increasing the number of components among the power elements.

[0010]

[Means of Solving the Problem] In order to solve this problem, the invention in claim 1 is a power source device comprising a full-wave rectifier for performing full-wave rectification of alternating current voltage from an alternating current power source to direct current voltage, an inverter consisting of a series circuit having a load resonance circuit including an LC resonance circuit and a load and having a pair of switches, the inverter being connected to the output of the full-wave rectifier, a smoothing capacitor for supplying the direct current voltage to the inverter, a discharge diode for supplying direct current power from the smoothing capacitor to the inverter, a current transformer for detecting the regenerative current flowing via one of the pair of switches, and a charging diode for directing the charge current from the output of the full-wave rectifier to the smoothing capacitor via the other switch and the current transformer, wherein the other switch is prevented from turning on when the current transformer detects the regenerative current.

[0011] In this configuration, the other switch among the pair of switches (i.e., the switch used to supply charging current to the smoothing capacitor) is kept from turning on when the current transformer detects a regenerative current. This reduces the regenerative current during the prohibited period. As a result, the stress on the switches can be reduced without increasing the number of components among the power elements.

[0012] This configuration can further comprise a separately-excited control circuit for generating an oscillation signal and using this oscillation signal to generate a control signal for turning the switches on and off (claim 2). As a result, the stress on the switches can be reduced without increasing the number of components among the power elements.

[0013] This configuration can further comprise a self-excited control circuit using the electromotive force induced by the drive coil magnetically connected to the current transformer to turn the switches to the inverter on and off, and the current transformer can be arranged in the route of the resonance current for the load resonance circuit (claim 3). As a result, the stress on the switches can be reduced without increasing the number of components among the power elements.

[0014] In this configuration, the current transformer and the drive coil can also consist of a saturable transformer (claim 4). When there is a large regenerative current flowing to the transformer in this configuration, the transformer becomes saturated and electromotive force is not induced into the drive coil. As a result, the switches to the inverter are not turned on by the control circuit, and the large regenerative current flowing to the transformer is reduced.

[0015] This configuration can further comprise an impedance element connected between the load resonance circuit and the output terminal of the full-wave rectifier (claim 5). This configuration improves the intake of current inputted from the alternating current power source. As a result, distortions in the inputted current can be improved.

[0016] This configuration can further comprise an impedance element connected in parallel to the current transformer (claim 6). In this configuration, the current flow to the current transformer can be adjusted by the flow of current to the impedance element.

[0017] In this configuration, the current transformer can be installed in one of the several routes for charging the smoothing capacitor (claim 7). This configuration can adjust the flow of current to the current transformer.

[0018] In this configuration, an inductor can be installed to divide and output the charging current to the smoothing capacitor, and the current transformer can be installed in one of the divided routes of the inductor (claim 8). This configuration can adjust the flow of current to the current transformer.

[0019] The invention in claim 9 is a power source device comprising a full-wave rectifier for performing full-wave rectification of alternating current voltage from an alternating current power source to direct current voltage, an inverter including a series circuit with a pair of switches for converting the direct current voltage to high-frequency voltage, a smoothing capacitor for supplying direct current power to the inverter, a discharge diode for supplying direct current voltage from the smoothing capacitor to the inverter, a transformer in which the primary coil is inserted between the output terminal of the inverter and the direct current output terminal of the full-wave rectifier, a load resonance circuit including an LC resonance circuit and a load, an impedance element for connecting the load resonance circuit to the full-wave rectifier, and a current transformer for detecting the regenerative current generated via the other switch by the charging current flowing to the smoothing capacitor via the one switch and a portion of the load resonance circuit when the one switch among the pair of switches is turned on, wherein the one switch is prevented from turning on when the current transformer detects the regenerative current.

[0020] In this configuration, the other switch among the pair of switches (i.e., the switch used to supply charging current to the smoothing capacitor) is kept from turning on when the current transformer detects a regenerative current. This reduces the regenerative current during the prohibited period. As a result, the stress on the switches can be reduced without increasing the number of components among the power elements.

[0021] The invention in claim 10 is a power source device comprising a full-wave rectifier for performing full-wave rectification of alternating current voltage to direct current voltage, a pair of switches connected in series between both output terminals of the full-wave rectifier, a direct current-preventing capacitor connected to one of the output terminals of the full-wave rectifier, a load resonance circuit consisting of an inductor, a capacitor including this inductor and an LC resonance circuit, and a load connected in parallel to this capacitor, the load resonance circuit being connected between the connection point for the pair of switches and the other terminal of the direct current-preventing capacitor, a smoothing capacitor connected to one of terminals to the pair of switches, a discharge diode connected to the other terminal to the pair of switches and the other terminal of the smoothing capacitor for directing flow of discharged current for the smoothing capacitor, a current transformer connected to the connection point for the pair of switches and one terminal of the primary coil for detecting the regenerative current flowing via the one switch, and a charging diode connected between the other terminal of the primary coil in the current transformer and the other terminal of the smoothing capacitor for directing the charging current of the smoothing capacitor when the other switch is turned on, wherein the other switch is prevented from turning on when the current transformer detects the regenerative current.

[0022] In this configuration, the other switch among the pair of switches (i.e., the switch used to supply charging current to the smoothing capacitor) is kept from turning on when the current transformer detects a regenerative current. This reduces the regenerative

current during the prohibited period. As a result, the stress on the switches can be reduced without increasing the number of components among the power elements.

[0023]

[Embodiment of the Invention] FIG 1 is a schematic diagram of the power source device in the first working example of the present invention. The following is an explanation of the first working example with reference to this drawing.

[0024] The power source device in FIG 1 comprises a full-wave rectifier DB for performing full-wave rectification of alternating current voltage from an alternating current power source Vs to direct current voltage, FETs Q1, Q2 (a pair of switches) connected in series between both output terminals of the full-wave rectifier DB, a direct current-preventing capacitor (impedance element) C11 with one end connected to the negative output terminal of the full-wave rectifier DB, an inductor L10, a capacitor C10 constituting an LC resonance circuit with the inductor L10, a load RL connected in parallel to the capacitor C10, a load resonance circuit LD1 connected between the connection points of the FETs Q1, Q2 and the other end of the capacitor C11, a smoothing capacitor CE10 with the positive terminal connected to the drain of the FET Q1, the inductor L11 with one end connected to the negative terminal of the capacitor CE10, a diode (discharge diode) D11 for directing the discharge current of the capacitor CE10 connected between the source of FET Q2 and the negative terminal of the capacitor CE10 (i.e., connected between the source of FET Q2 and the other terminal of the inductor L11), a saturable current transformer (hereinafter, referred to simply as the transformer) CT10 having a primary coil n1 with one end connected to the connection point of the FETs Q1, Q2 along with a secondary coil n2 for detecting the regenerative current flowing via the FET Q1 end, a diode (charging diode) D12 connected between the other end of the primary coil n1 of the transformer CT10 and the other end of the inductor L11 for directing the charging current of the capacitor CE1 when FET Q2 is turned on, and a capacitor C12 connected to capacitor CE10, inductor L11 and diode D11.

[0025] However, FETs Q1 and Q2 have parasitic diodes DQ1 and DQ2, respectively, connected in parallel. An inverter is also configured from the FETs Q1, Q2 and a load resonance circuit LD1. Power is supplied to this inverted from capacitor CE10 via diode D11. A step-down chopper is also configured with FET Q2 in the inverter. It consists of capacitor CE10, inverter L11, diode D12 and FET Q2. In addition, a control circuit is installed to turn on and off FETs Q1 and Q2.

[0026] The control circuit comprises a detection circuit 11 connected to the secondary coil n2 in the transformer CT10 for detecting magnetic saturation of the transformer CT10, an oscillation circuit 12 for generating a predetermined oscillation signal, and a drive circuit 13 for generating an ON/OFF drive signal using the oscillation signal from the oscillation circuit 12, operating the FETs Q1, Q2 using this drive signal, and preventing the FETs Q1, Q2 from being turned on when magnetic saturation of the transformer CT10 is detected by the detection circuit 11. This drive circuit 13 is configured to initially send a drive signal to FET Q2 at startup.

[0027] FIG 2 is a diagram used to explain the operation of the power source device in FIG 1. The following is a simplified explanation of the operation of the first working example with reference to this drawing.

[0028] When FET Q2 is turned on, as shown in FIG 2 (a), charging current flows on the step-down chopper side to the route (closed loop) consisting of alternating current power

source Vs, full-wave rectifier DB, capacitor CE10, inductor L11, diode D12, transformer CT10, FET Q2, full-wave rectifier DB and alternating current power source Vs. Capacitor CE10 is charged by the charging current, and magnetic energy is stored in the inductor L11. On the inverter side, resonance current flows to capacitor C11, the parallel circuit with capacitor C10 and load RL, inductor L10, FET Q2 and capacitor C11.

[0029] Afterwards, when FET Q2 is turned off, as shown in FIG 2 (b), the magnetic energy stored in the inductor L11 causes regenerative current to flow in the route consisting of inductor L11, diode D12, transformer CT10, parasitic diode DQ1, capacitor CE10 and inductor L11, and the magnetic energy stored in inductor L11 is discharged to capacitor CE10. Resonance current flows through the route consisting of inductor L10, parasitic diode DQ1, capacitor C12, capacitor C11, the parallel circuit with capacitor C10 and load RL, and inductor L10.

[0030] Afterwards, the resonance current is commutated as shown in FIG 2 (c) and flows through the route consisting of capacitor C12, parasitic diode DQ1, inductor L10, the parallel circuit with capacitor C10 and load RL, capacitor C11 and capacitor C12. A forward-moving bias current flows to parasitic diode DQ1 due to the regenerative current, this resonance current can flow through parasitic diode DQ1.

[0031] FIG 3 is a waveform diagram of the signals for the various components in the power source device of FIG 1. The stress-reduction principles for the switching elements will now be explained with reference to this drawing. In FIG 3, Ic is the current flowing through the step-down chopper side, V11 is the output signal from detection circuit 11, Vosc is the output signal from oscillation circuit 12, and VG2 is the waveforms of the drive signal for FET Q2 from drive circuit 13.

[0032] When FET Q2 is turned on at the startup of the circuit (time t11), the charging current Ic flows on the step-down chopper side to the route indicated by the solid lines in FIG 2 (a). Because the charging potential of capacitor CE10 is low and the potential difference between capacitor CE10 and alternating current power source Vs is high at this time, charging current Ic is a large current. When this large charging current Ic flows to transformer CT10, transformer CT10 becomes magnetically saturated, and a high-level signal V11 is outputted from the detection circuit 11 used to detect this state (time t12).

[0033] When the high-level signal V11 is taken up by drive circuit 13, the drive signal for turning on FETs Q1 and Q2 is not outputted, and FETs Q1 and Q2 remain turned off. During the off state, the circuit operation shown in FIG 2 (b) and (c) is repeated, and the regenerative current Ic in the step-down chopper is reduced.

[0034] Afterwards, this regenerative current Ic is reduced. When the transformer CT10 is released from a magnetically saturated state, a low-level signal V11 is outputted from the detection circuit 11 (time t13). When this low-level signal V11 is taken up by the drive circuit 13, the drive circuit 13 is released from stopping (prohibiting) output of a drive signal to turn on FETs Q1 and Q2. This signal allows FETs Q1 and Q2 to be turned on.

[0035] Later, when drive signal VG2 obtained from signal Vosc of oscillation circuit 12 is sent to FET Q2 from the drive circuit 13 (time t14), FET Q2 is turned on. Before FET Q2 is turned on, as shown in FIG 3, a high-level signal V11 is outputted from detection circuit 11 (time t15). Afterwards, the drive signal for turning on FETs Q1 and Q2 is not outputted from drive circuit 13, and FETs Q1 and Q2 remain turned off.

[0036] This operation reduces the charging current of capacitor CE10 and is repeated until transformer CT10 becomes magnetically saturated. When transformer CT10 is no longer magnetically saturated, drive signals VG1 and VG2 for turning off and on FETs Q1 and Q2 are outputted from drive circuit 11.

[0037] In the first working example, when the regenerative current flowing through capacitor CE10 is large after FET Q2 has been turned off, this state is detected by the magnetic saturation of transformer CT10. By preventing the output of a drive signal from drive circuit 13 to turn on FET Q2, FET Q2 can be turned on only when the regenerative current flowing through the parasitic diode DQ1 is small. As a result, flow of "simultaneous ON" current to the circuit can be prevented.

[0038] Simultaneous ON can be prevented using a saturable current transformer instead of a power element such as a transistor or resistance.

[0039] FET Q2 can also be prevented from turning on using the level of the regenerative current flowing through the circuit.

[0040] In the first working example, the configuration uses FETs Q1 and Q2. However, the present invention is not limited to this. It can be configured from other switching elements such as transistors. Here, an inverse-parallel connection is created between the diode and the various switching elements.

[0041] FIG 4 is a schematic diagram of the power source device in the second working example of the present invention. The following is an explanation of the second working example using this drawing. The components identical to those in the previous working example are denoted by the same numbers.

[0042] The full-wave rectifier DB, FETs Q1, Q2, capacitors C11, C12, load resonance circuit LD1, capacitor CE10, inductor L11 and diodes D11, D12 in power source device in FIG 4 are identical to those in the first working example. This working example differs from the first working example with the inclusion of current transformer CT20 (hereinafter, referred to simply as the transformer) having a primary coil n21 interposed between the load resonance circuit LD1 and the connection point of FETs Q1 and Q2, where one end of the coil is connected to this connection point, and having secondary coils n22 and n23. It also includes a separate control circuit for turning FETs Q1 and Q2 on and off.

[0043] This control circuit has a start circuit 20 for starting the oscillation and a self-exciting drive circuit consisting of secondary coil n22, gate resistance R1 connected in series between the secondary coil n22 and the source-drain of FET Q1, secondary coil n23, and gate resistance R2 connected in series between the secondary coil n23 and the source-drain of FET Q2.

[0044] This start circuit 20 comprises resistance Rg connected in series between both output terminals of the full-wave rectifier DB, a capacitor Cg, a diode Dg connected between the connection point for these and the other end of the primary coil n21, and a trigger diode (Diac) Tg connected between the same connection point and the connection point between resistance R2 and the secondary coil n23. When the voltage value of the capacitor Cg, which is gradually charged via resistance Rg once the power is turned on, exceeds the threshold value of the Diac Tg, the voltage of the capacitor Cg is applied to the gate of FET Q2 and the transistor is turned on.

[0045] However, the transformer CT20 detects the regenerative current flowing through the FET Q1 side and becomes magnetically saturated if the regenerative current is large. Also, the coils in the transformer CT20 have the polarities shown in FIG 4. In other words, the circuit resonance applies voltage with opposite polarities to the gates of FET Q1 and Q2, and it is the polarities turn FET Q1 and Q2 on and off.

[0046] FIG 5 is a diagram used to explain the operation of the power source device in FIG 4. There follows a simplified explanation of the operation of the second working example with reference to this drawing. However, the start circuit 20 has been omitted from FIG 5.

[0047] When FET Q2 is turned on, as shown in FIG 5 (a), the charging current flows on the step-down chopper side to the route consisting of alternating current power source Vs, full-wave rectifier DB, capacitor CE10, inductor L11, diode D12, transformer CT20, FET Q2, full-wave rectifier DB and alternating current power source Vs. Capacitor CE10 is charged by the charging current, and magnetic energy is stored in inductor L11. The resonance current flows on the inverter side to the route consisting of capacitor C11, the parallel circuit with capacitor C10 and load RL, inductor L10, transformer CT20, FET Q2 and capacitor C11.

[0048] When the secondary side voltage of transformer CT20 is reversed, FET Q2 is turned off. As shown in FIG 5 (b), the magnetic energy stored in inductor L11 causes the regenerative current to flow to the route consisting of inductor L11, diode D12, transformer CT20, parasitic diode DQ1, capacitor CE1 and inductor L11, and the magnetic energy stored in inductor L11 is discharged to capacitor CE10. On the load resonance circuit LD1 side, the resonance current flows to the route consisting of inductor L10, transformer CT20, parasitic diode DQ1, capacitor C12, capacitor C11, the parallel circuit with capacitor C10 and load RL, and inductance L10.

[0049] Afterwards, the resonance current is commutated as shown in FIG 5 (c) and flows through the route consisting of capacitor C12, parasitic diode DQ1, capacitor CT20, inductor L10, the parallel circuit with capacitor C10 and load RL, capacitor C11 and capacitor C12.

[0050] FIG 6 is a signal waveform diagram for the power source device in FIG 4. The stress-reduction principles for the switching elements will now be explained with reference to this drawing.

[0051] When FET Q2 is turned on at the startup of the circuit (time t21), the charging current Ic flows on the step-down chopper side to the route indicated by the solid lines in FIG 5 (a). Because the charging potential of capacitor CE10 is low and the potential difference between capacitor CE10 and alternating current power source Vs is high at this time, charging current Ic is a large current.

[0052] Here, the drive circuit constituting the control circuit in the second working example is self-exciting. A current consisting of the convergence of the resonance current flowing through the inductor L10 and the step-down chopper current flowing through the inductor L11 flows to the transformer CT20, and a drive signal is generated for FETs Q1 and Q2 by this convergent current. Therefore, when a large charging current (step-down chopper current) flows to the transformer CT20, the transformer CT20 becomes magnetically saturated and start power is not generated on the secondary side. As a result a drive signal is not generated for the FETs Q1, Q2. In other words, the output of drive signals for turning on the FETs Q1, Q2 is stopped, and the gate voltages for both FETs Q1, Q2 drops to zero.

[0053] When the gate voltage of FET Q2 drops to zero as shown in FIG 6, FET Q2 is turned off (time t22). While the transistor is turned off, the circuit operation shown in FIG 5 (b) and (c) is repeated and the regenerative current for the step-down chopper is reduced.

[0054] Afterwards, when the regenerative current is small and the transformer CT20 has been released from a magnetically saturated state, the stopping of the output of drive signals for turning on the FETs Q1, Q2 is released. This enables FETs Q1 and Q2 to be turned on.

[0055] When the series of operations charging capacitor CE10 has been continued for a long while, the charging current for capacitor CE10 becomes gradually smaller. Transformer CT20 is no longer magnetically saturated and oscillation is continuous.

[0056] Because the transformer CT20 in the second working example has both an oscillating function and an oscillation stopping function, simultaneous ON can be suppressed using a simple circuit configuration.

[0057] FIG 7 is a schematic diagram of the power source device in the third working example of the present invention. The following is an explanation of the third working example with reference to this drawing.

[0058] The power source device in FIG 7 is similar to the second working example in that it is equipped with full-wave rectifier DB, FETs Q1 and Q2, capacitors C11 and C12, capacitor CE10, inductor L11, diodes D11 and D12, and transformer CT20. However, it differs from the second working example in that it is also equipped with capacitor C13 interposed between the negative output terminal of the full-wave rectifier DB and the source of FET Q2, diode D13 connected in parallel to capacitor C13, and load resonance circuit LD2.

[0059] This load resonance circuit LD2 comprises a discharge lamp La with a pair of filaments, a leakage transformer (hereinafter referred to simply as the transformer) T1 having a primary coil interposed between capacitor C11 and transformer CT20 and a second coil connected in parallel with one end of both filaments in the discharge lamp La, and capacitor 10 connected in parallel to the other ends of the filaments in the discharge lamp La. This transformer T1 is designed with a leak inductance component that corresponds to inductance L10 in the load resonance circuit LD1 of the second working example. In other words, the resonance circuit comprises the leak inductance component and capacitor C10.

[0060] FIG 8 is a diagram used to explain the operation of the power source device in FIG 7. The operation of the third working example will now be explained with reference to this drawing. The start circuit 20 has been omitted from FIG 8.

[0061] When FET Q2 is turned on, as shown in FIG 8 (a), the charging current flows on the step-down chopper side through the route consisting of alternating current power source Vs, full-wave rectifier DB, capacitor CE10, inductor L11, diode D12, transformer CT20, FET Q2, diode D13, full-wave rectifier DB and alternating current power source Vs. This charging current charges capacitor CE10 and magnetic energy is stored in inductor L11. On the inverter side, the resonance current flows through the route consisting of capacitor C11, transformer T1, transformer CT20, FET Q2, diode D13 and capacitor C11.

[0062] Afterwards, when the secondary voltage of transformer CT20 is reversed, FET Q2 is turned off. As shown in FIG 8 (b), the magnetic energy stored in inductor L11 causes the regenerative current to flow to the route consisting of inductor L11, diode D12, transformer CT20, parasitic diode DQ1, capacitor CE10 and inductor L11, and the magnetic energy

stored in inductor L11 is discharged to capacitor CE10. The resonance current flows to the route consisting of transformer T1, transformer CT20, parasitic diode DQ1, capacitor C12, capacitor C11 and transformer T1.

[0063] Afterwards, when the resonance current is reversed, it flows as shown in FIG 8 (c) through the route consisting of capacitor C12, parasitic diode DQ1, transformer CT20, transformer T1, capacitor C11, capacitor C13 and capacitor C12. This resonance current flows through this route and causes vibrations to the extent that the step-down chopper current is flowing to parasitic diode DQ1.

[0064] When the resonance current causes a difference in potential between the charge voltage of charged capacitor C13 and both the alternating current power source Vs and capacitor C12, input current flows to the route indicated by the solid line in FIG 8 (a), and input current flows in response to the high-frequency of the input voltage. This reduces input voltage distortion.

[0065] During this operation, when the convergent current consisting of the resonance current and the regenerative current flowing through transformer CT20 is large enough to cause transformer CT20 to become magnetically saturated, the oscillation voltage caused by the resonance induced to the secondary side of transformer CT20 is extinguished and FET Q2 cannot be turned on. In other words, output of the drive signal for turning on FET Q1 and Q2 is stopped. Thus, as the circuit operation in FIG 8 (b) and (c) is repeated, the regenerative current on the step-down chopper side becomes smaller. When the regenerative current has become smaller and transformer CT20 has been released from a magnetically saturated state, the stopping of the output of the drive circuit for turning on FETs Q1 and Q2 is released. This allows the FETs Q1, Q2 to be turned on.

[0066] As explained above, in addition to providing an effect similar to the second working example, the third working example also reduces input current distortion.

[0067] FIG 9 is a schematic diagram of the power source device in the fourth working example of the present invention. The following is an explanation of the fourth working example with reference to this drawing.

[0068] The power source device in FIG 9 is identical to the third working example except that diode D12 is connected between capacitor CE10 and the connection point of capacitor C11 and transformer T1, and inductor L11 is replaced by self-exciting inductance.

[0069] FIG 10 is a diagram used to explain the operation of the power source device in FIG 9. The operation of the fourth working example will now be explained with reference to this drawing. The start circuit 20 has been omitted from FIG 10.

[0070] When FET Q2 is turned on by the start circuit 20, as shown in FIG 10 (a), the charging current flows through the route consisting of alternating current power source Vs, full-wave rectifier DB, capacitor CE10, diode D12, transformer T1, transformer CT20, FET Q2, diode D13, full-wave rectifier DB and alternating current power source Vs. This charging current charges capacitor CE10 and magnetic energy is stored in inductor L11. The resonance current flows through the route consisting of capacitor C11, transformer T1, transformer CT20, FET Q2, diode D13 and capacitor C11.

[0071] Afterwards, when the secondary side voltage of transformer CT20 is reversed, FET Q2 is turned off. As shown in FIG 10 (b), the convergent current consisting of the regenerative current and the resonance current flows through the route consisting of

transformer T1, transformer CT20, parasitic diode DQ1, capacitor CE10, diode D12 and transformer T1.

[0072] Afterwards, as shown in FIG 10 (c), the resonance current is reversed through the same route, and vibration occurs when the step-down chopper current (regenerative current) is smaller than the reversed resonance current.

[0073] During this operation, when the convergent current consisting of the resonance current and the regenerative current flowing through transformer CT20 is large enough to cause transformer CT20 to become magnetically saturated, the oscillation voltage caused by the resonance induced to the secondary side of transformer CT20 is extinguished and FET Q2 cannot be turned on. Thus, as the circuit operation in FIG 10 (b) and (c) is repeated, the regenerative current on the step-down chopper side becomes smaller. When the regenerative current has become smaller and transformer CT20 has been released from a magnetically saturated state, the stopping of the output of the drive circuit for turning on FETs Q1 and Q2 is released. This allows the FETs Q1, Q2 to be turned on. In other words, the fourth working example has the same effect as the third working example.

[0074] FIG 11 is a schematic diagram of the power source device in the fifth working example of the present invention. The following is an explanation of the fifth working example with reference to this drawing.

[0075] The power source device in FIG 11 has the same configuration as the third working example except that the inductance element Z is connected in parallel to the primary coil n21 in transformer CT20.

[0076] This inductance element Z has the same characteristics as a low band pass filter and adjusts the convergent current consisting of the regenerative current and the resonance current flowing through transformer CT20 so that only the step-down chopper current passes through and the saturation level of transformer CT20 remains satisfactory for circuit operation.

[0077] In the fifth working example, the magnetic saturation characteristics of transformer CT20 are used to reduce the stress on the switching elements. However, the oscillation during normal operation has to be stabilized. The design can become complicated when satisfactory adjustment in both cases depends solely on the characteristics of transformer CT20.

[0078] However, the installation of impedance element Z can be utilized to divide the step-down chopper current and adjust the current flowing to transformer CT20. Because enough current for the magnetic saturation of the transformer CT20 to be used for desirable circuit operation can flow to impedance element Z, the circuit design needed to prevent simultaneous ON is simplified and the design needed for stable operation during rated lighting is also simplified.

[0079] FIG 12 is a schematic diagram of the power source device in the sixth working example of the present invention. The following is an explanation of the sixth working example with reference to this drawing.

[0080] The power source device in FIG 12 comprises a full-wave rectifier DB for performing full-wave rectification of alternating current voltage from an alternating current power source Vs to direct current voltage, diode D13 in which the cathode is connected in the forward direction to the negative output terminal of the full-wave rectifier DB, capacitor C13

connected in parallel to diode D13, FETs Q1 and Q2 connected in series between both output terminals of the full-wave rectifier DB (i.e., between the positive output terminal of the full-wave rectifier DB and the anode of diode D13), a direct current-preventing capacitor C11 in which one end is connected to the negative output terminal of the full-wave rectifier DB, a load resonance circuit LD2 connected between the connection point of the FETs Q1, Q2 and the other end of capacitor C11, inductance L11 in which one end is connected to the drain of FET Q1, a smoothing capacitor CE10 in which the positive terminal is connected to the drain of FET Q1 via inductor L11, a diode D11 connected between the source of FET Q2 and capacitor CE10 for allowing the discharge current from capacitor CE10 to flow, a transformer CT20 interposed between transistor T1 and the connection point of the FETs Q1, Q2 and having a primary coil n21 secondary coils n22, 23 connected on one end to this connection point for detecting the regenerative current flowing via the FET Q1 side, a diode D12 connected between the other end of the primary coil n21 of transformer CT20 and the negative terminal of capacitor CE10 for allowing the charge current in capacitor CE10 to flow when FET Q2 is turned on, and a control circuit. This configuration is nearly identical to the first working example. It is, in fact, identical to the first working example except that the arrangement of the inductance L11 and the capacitor CE10 has been reversed in the circuit configuration.

[0081] This power source device is also equipped with a capacitor CE20 in which the positive terminal is connected to the other terminal of inductance L11, a diode D12 connected between the negative terminal of the capacitor CE20 and the source of FET Q2 to allow the discharge current of capacitor CE20 to flow, and a diode D22 connected between the connection point of the FETs Q1, Q2 and the negative terminal of capacitor CE20 for allowing the charge current of capacitor CE20 to flow.

[0082] In other words, the sixth working example is configured so that the capacitor on the step-down chopper end is divided into capacitor CE10 and capacitor CE20, and the step-down chopper current is divided between a route flowing through transformer CT20 and a route not flowing through the transformer.

[0083] With this configuration, the sixth working example can adjust the convergent current consisting of the resonance current and the regenerative current flowing through transformer CT20 as in the fifth working example. As a result, the circuit design needed to prevent simultaneous ON is simplified and the design needed for stable operation during rated lighting is also simplified.

[0084] FIG 13 is a schematic diagram of the power source device in the seventh working example of the present invention. The following is an explanation of the seventh working example with reference to this drawing.

[0085] The power source device in FIG 13 has the same configuration as the seventh [sic] working example except that the primary coil n21 of the transformer CT20 is installed on the secondary side of transformer T1. One end of the primary coil n21 is connected to the secondary coil of transformer T1 and to the connection point of the FETs Q1, Q2, and the other end of the primary coil n21 is connected to an end of one of the filaments in the discharge lamp La and to the cathode of diode D12.

[0086] The installation of transformer CT20 on the secondary side of transformer T1 reduces the current flowing to transformer CT20. This can make transformer CT20 more compact and can improve the design properties of the oscillation circuit.

[0087] Because the capacitor on the step-down chopper end is divided into capacitor CE10 and capacitor CE20, and because the step-down chopper current is divided between a route flowing through transformer CT20 and a route not flowing through the transformer, the convergent current consisting of the resonance current and the regenerative current flowing through transformer CT20 can be adjusted. As a result, the circuit design needed to prevent simultaneous ON is simplified and the design needed for stable operation during rated lighting is also simplified.

[0088] FIG 14 is a schematic diagram of the power source device in the eighth working example of the present invention. The following is an explanation of the eighth working example with reference to this drawing.

[0089] The power source device in FIG 14 comprises a full-wave rectifier DB for performing full-wave rectification of alternating current voltage from an alternating current power source Vs to direct current voltage, diode D13 in which the cathode is connected in the forward direction to the negative output terminal of the full-wave rectifier DB, capacitor C13 connected in parallel to diode D13, FETs Q1 and Q2 connected in series between both output terminals of the full-wave rectifier DB (i.e., between the positive output terminal of the full-wave rectifier DB and the anode of diode D13), a direct current-preventing capacitor C11 in which one end is connected to the negative output terminal of the full-wave rectifier DB, a load resonance circuit LD2 connected between the connection point of the FETs Q1, Q2 and the other end of capacitor C11, a smoothing capacitor CE10 in which the positive terminal is connected to the drain of FET Q1, inductance L21 with an intermediate tap in which one end is connected to the negative terminal of capacitor CE10, a diode D11 connected between the source of FET Q2 and capacitor CE10 (i.e., between the source of FET Q2 and the other end of inductor L21) for allowing the discharge current from capacitor CE10 to flow, a transformer CT20 interposed between transistor T1 and the connection point of the FETs Q1 with a primary coil n21 connected on one end to this connection point for detecting the regenerative current flowing via the FET Q1 side, inductance element Z connected on one end to the intermediate tap of inductor L21, a diode D12 connected between the other end of the primary coil n21 and the negative terminal of capacitor CE10 (i.e., connected between the other end of the primary coil n21 and the other end of impedance element Z) for allowing the charge current in capacitor CE10 to flow when FET Q2 is turned on, diode D32 connected between the connection point of FETs Q1, Q2 and the other end of inductor L21 for allowing the discharge current of capacitor CE10 to flow, and a control circuit identical to the one in the third working example.

[0090] In other words, in the eighth working example, the inductor L21 on the step-down chopper side is essentially divided in two by an intermediate tap, and the step-down chopper current is divided between the route flowing from the intermediate tap in inductor L21 through transformer CT20 via impedance element Z and diode D12, and the route not flowing to transformer CT20 from the other end of inductor L21 via diode D32.

[0091] In this configuration, the properties of impedance element Z enables the proper current to flow to transformer CT20 when the magnetic saturation of transformer CT20 is used in the desired circuit operation. In other words, adequate current can flow to the diode D32 side when the magnetic saturation of transformer CT20 is used in the desired circuit operation. As a result, the circuit design for preventing simultaneous ON is simplified, and the design for safe operation during rated lighting is also simplified. This can also reduce the number of elements needed to divide the current in the sixth working example.

[0092] FIG 15 is a schematic diagram of the power source device in the ninth working example of the present invention. The following is an explanation of the ninth working example with reference to the drawings.

[0093] The power source device in FIG 15 has the same configuration as the eighth working example except that the primary coil n21 in the transformer CT20 is interposed in the secondary side of transformer T1. One end of the primary coil n21 is connected to the secondary coil of transformer T1 and connected to the connection point of FETs Q1, Q2, and the other end of the primary coil n21 is connected to one end of a filament in the discharge lamp La and connected to the cathode of diode D12.

[0094] In addition to having the same effect as the eight working example, the installation of transformer CT20 on the secondary side of transformer T1 reduces the current flowing to transformer CT20. This allows transformer CT20 to be more compact. It also improves the design properties of the oscillation circuit.

[0095]

[Effect of the Invention] The invention in claim 1 is a power source device comprising a full-wave rectifier for performing full-wave rectification of alternating current voltage from an alternating current power source to direct current voltage, an inverter consisting of a series circuit having a load resonance circuit including an LC resonance circuit and a load and having a pair of switches, the inverter being connected to the output of the full-wave rectifier, a smoothing capacitor for supplying the direct current voltage to the inverter, a discharge diode for supplying direct current power from the smoothing capacitor to the inverter, a current transformer for detecting the regenerative current flowing via one of the pair of switches, and a charging diode for directing the charge current from the output of the full-wave rectifier to the smoothing capacitor via the other switch and the current transformer, wherein the other switch is prevented from turning on when the current transformer detects the regenerative current. As a result, the stress on the switches can be reduced without increasing the number of components among the power elements.

[0096] The invention in claim 2 further comprises a separately-excited control circuit for generating an oscillation signal and using this oscillation signal to generate a control signal for turning the switches on and off. As a result, the stress on the switches can be reduced without increasing the number of components among the power elements.

[0097] The invention in claim 3 further comprises a self-excited control circuit using the electromotive force induced by the drive coil magnetically connected to the current transformer to turn the switches to the inverter on and off, and wherein the current transformer is arranged in the route of the resonance current for the load resonance circuit. As a result, the stress on the switches can be reduced without increasing the number of components among the power elements.

[0098] In the invention in claim 4, the current transformer and the drive coil consist of a saturable transformer. This can reduce a large regenerative current flowing to the transformer.

[0099] The invention in claim 5 further comprises an impedance element connected between the load resonance circuit and the output terminal of the full-wave rectifier. This can improve the inputted current distortion.

[0100] The invention in claim 6 further comprises an impedance element connected in parallel to the current transformer. This can adjust the current flowing to the current transformer.

[0101] In the invention in claim 7, the current transformer is installed in one of the several routes for charging the smoothing capacitor. This can adjust the current flowing to the current transformer.

[0102] In the invention in claim 8, an inductor is installed to divide and output the charging current to the smoothing capacitor, and the current transformer is installed in one of the divided routes of the inductor. This can adjust the current flowing to the current transformer.

[0103]

The invention in claim 9 is a power source device comprising a full-wave rectifier for performing full-wave rectification of alternating current voltage from an alternating current power source to direct current voltage, an inverter including a series circuit with a pair of switches for converting the direct current voltage to high-frequency voltage, a smoothing capacitor for supplying direct current power to the inverter, a discharge diode for supplying direct current voltage from the smoothing capacitor to the inverter, a transformer in which the primary coil is inserted between the output terminal of the inverter and the direct current output terminal of the full-wave rectifier, a load resonance circuit including an LC resonance circuit and a load, an impedance element for connecting the load resonance circuit to the full-wave rectifier, and a current transformer for detecting the regenerative current generated via the other switch by the charging current flowing to the smoothing capacitor via the one switch and a portion of the load resonance circuit when the one switch among the pair of switches is turned on, wherein the one switch is prevented from turning on when the current transformer detects the regenerative current. As a result, the stress on the switches can be reduced without increasing the number of components among the power elements.

[0104] The invention in claim 10 is a power source device comprising a full-wave rectifier for performing full-wave rectification of alternating current voltage to direct current voltage, a pair of switches connected in series between both output terminals of the full-wave rectifier, a direct current-preventing capacitor connected to one of the output terminals of the full-wave rectifier, a load resonance circuit consisting of an inductor, a capacitor including this inductor and an LC resonance circuit, and a load connected in parallel to this capacitor, the load resonance circuit being connected between the connection point for the pair of switches and the other terminal of the direct current-preventing capacitor, a smoothing capacitor connected to one of terminals to the pair of switches, a discharge diode connected to the other terminal to the pair of switches and the other terminal of the smoothing capacitor for directing flow of discharged current for the smoothing capacitor, a current transformer connected to the connection point for the pair of switches and one terminal of the primary coil for detecting the regenerative current flowing via the one switch, and a charging diode connected between the other terminal of the primary coil in the current transformer and the other terminal of the smoothing capacitor for directing the charging current of the smoothing capacitor when the other switch is turned on, wherein the other switch is prevented from turning on when the current transformer detects the regenerative current. As a result, the stress on the switches can be reduced without increasing the number of components among the power elements.

[Brief Explanation of the Drawings]

[FIG 1] A schematic diagram of the power source device in the first working example of the present invention.

[FIG 2] A diagram used to explain the operation of the power source device in FIG 1.

[FIG 3] A signal waveform diagram for the various components in the power source device in FIG 1.

[FIG 4] A schematic diagram of the power source device in the second working example of the present invention.

[FIG 5] A diagram used to explain the operation of the power source device in FIG 4.

[FIG 6] A signal waveform diagram for the various components in the power source device in FIG 4.

[FIG 7] A schematic diagram of the power source device in the third working example of the present invention.

[FIG 8] A diagram used to explain the operation of the power source device in FIG 7.

[FIG 9] A schematic diagram of the power source device in the fourth working example of the present invention.

[FIG 10] A diagram used to explain the operation of the power source device in FIG 9.

[FIG 11] A schematic diagram of the power source device in the fifth working example of the present invention.

[FIG 12] A schematic diagram of the power source device in the sixth working example of the present invention.

[FIG 13] A schematic diagram of the power source device in the seventh working example of the present invention.

[FIG 14] A schematic diagram of the power source device in the eighth working example of the present invention.

[FIG 15] A schematic diagram of the power source device in the ninth working example of the present invention.

[FIG 16] A schematic diagram of a power source device of the prior art.

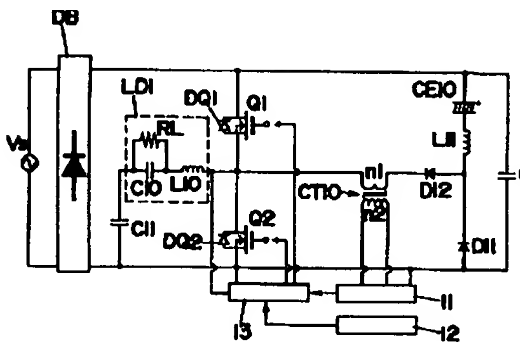
[FIG 17] A schematic diagram of another power source device of the prior art.

[Key to the Drawings]

DB	Full-Wave Rectifier
Q1, Q2	FET
C10-C12	Capacitors
CE10	Capacitor
L10, L11	Inductors
RL	Load

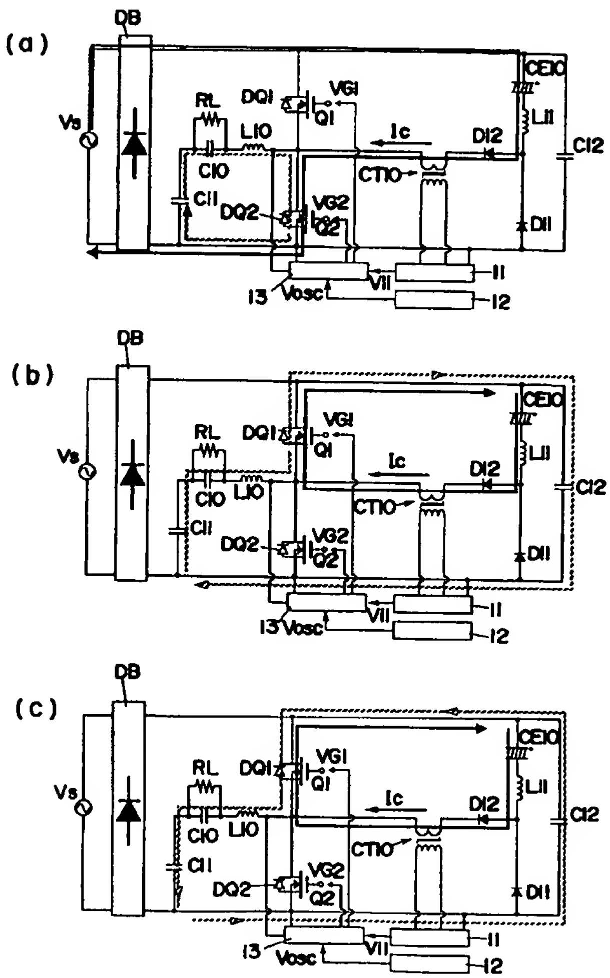
La	Discharge Lamp
LD1, LD2	Load Resonance Circuit
D11, D12	Diodes
CT10	Transformer (Current Transformer)

[FIG 1]



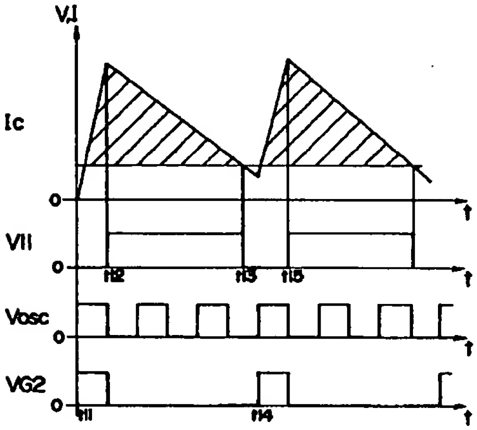
DB	Full-Wave Rectifier
Q1, Q2	FET
C10-C12	Capacitors
CE10	Capacitor
L10, L11	Inductors
RL	Load
LD1, LD2	Load Resonance Circuit
D11, D12	Diodes
CT10	Transformer (Current Transformer)
11	Detection Circuit
12	Oscillation Circuit
13	Drive Circuit

[FIG 2]

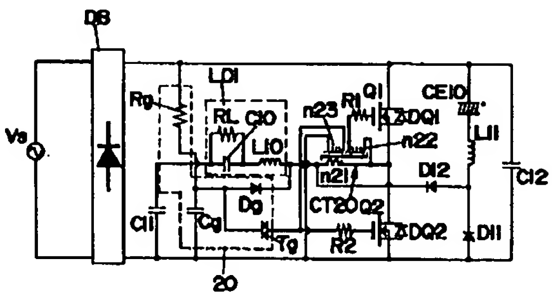


11	Detection Circuit
12	Oscillation Circuit
13	Drive Circuit

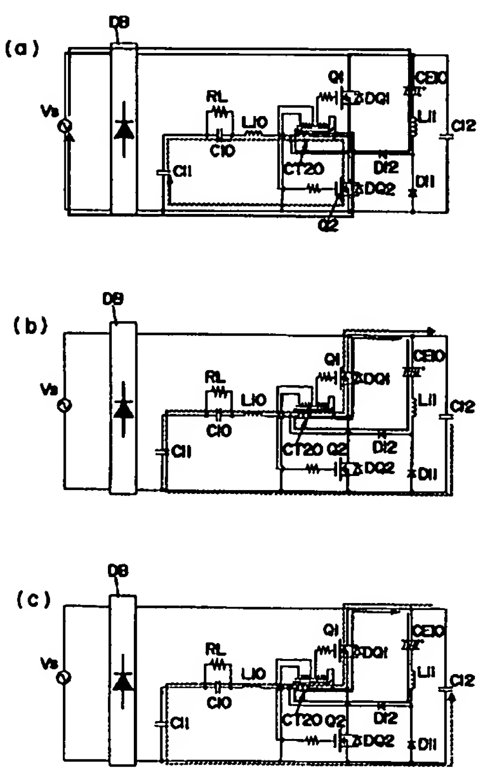
[FIG 3]



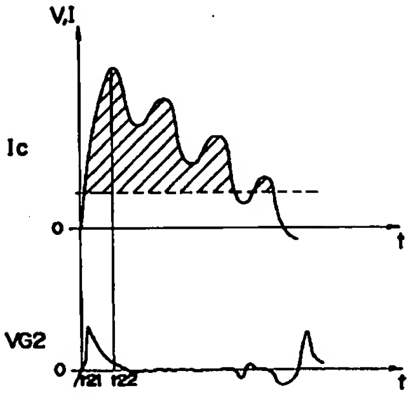
[FIG 4]



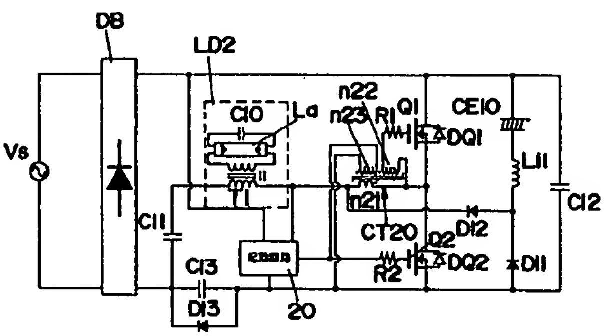
[FIG 5]



[FIG 6]

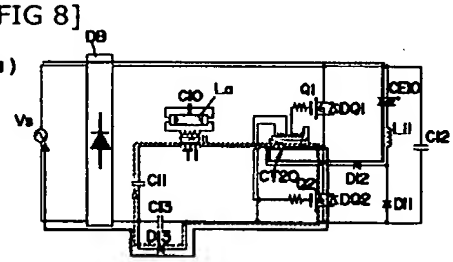


[FIG 7]



[FIG 8]

(a)



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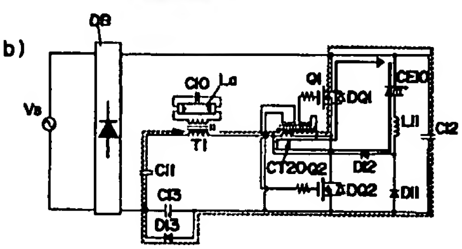
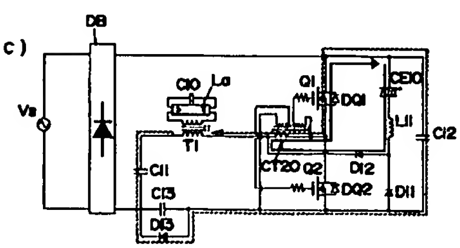
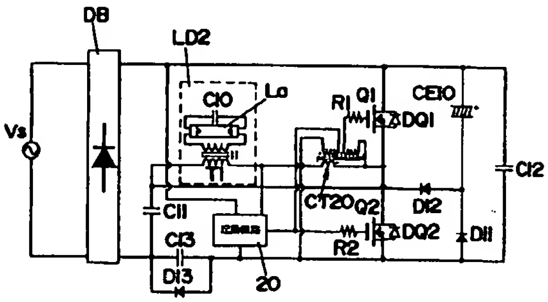


(c)

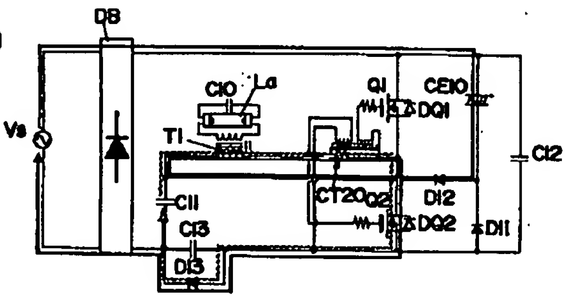


[FIG 9]



[FIG 10]

(a)



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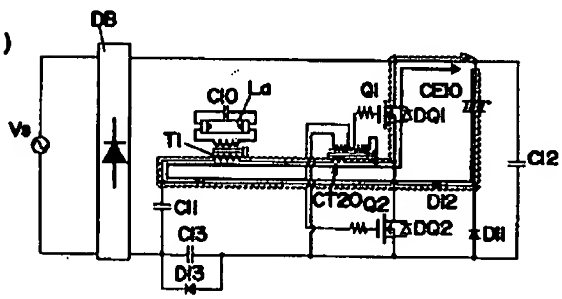
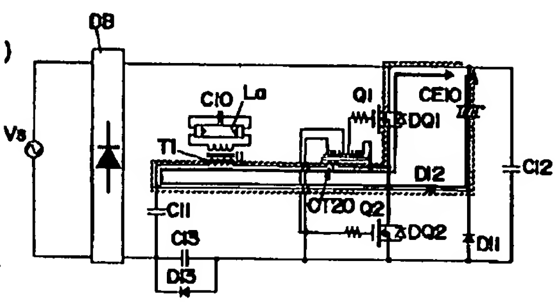
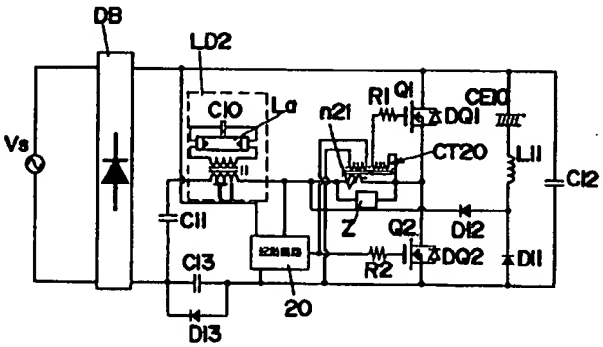


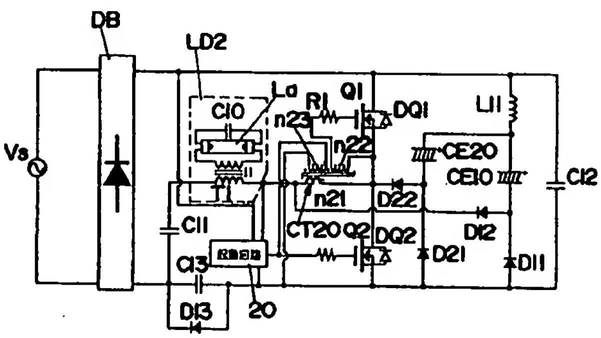
(c)



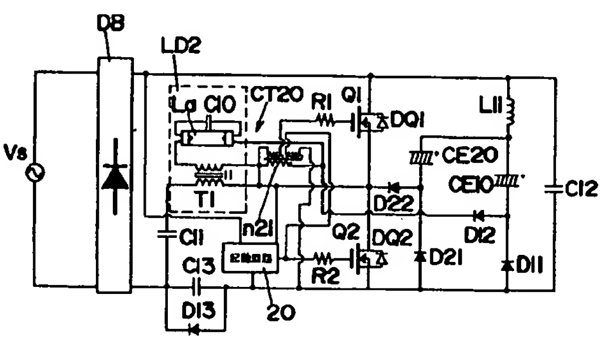
[FIG 11]



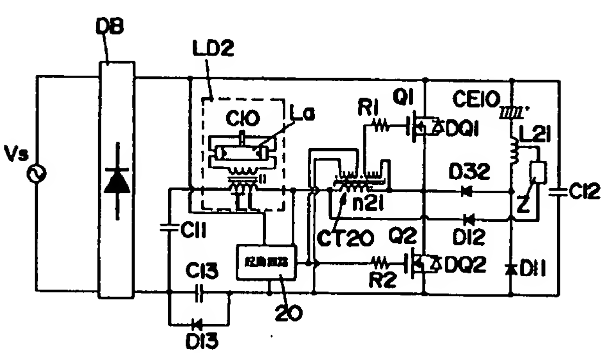
[FIG 12]



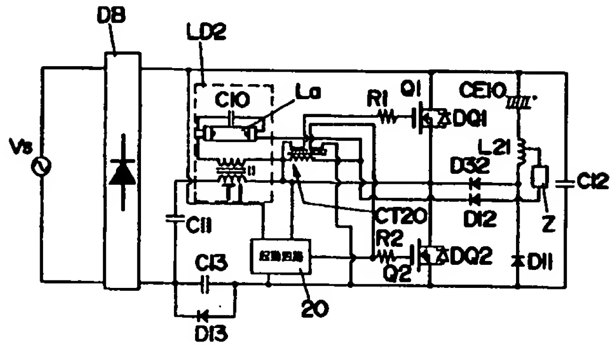
[FIG 13]



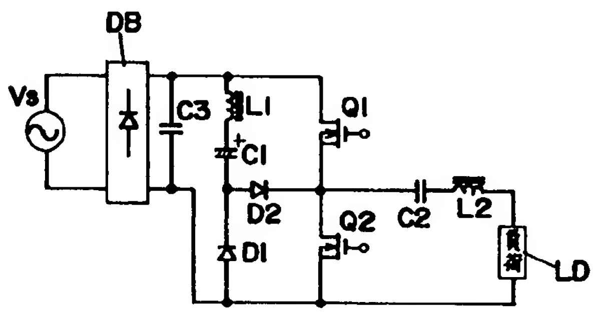
[FIG 14]



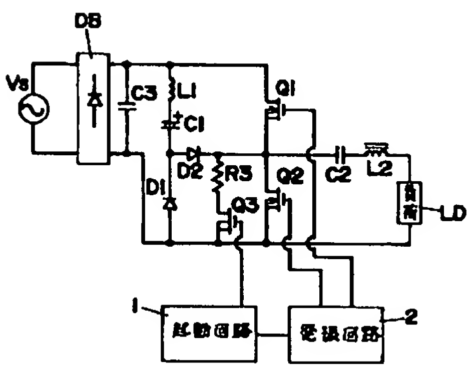
[FIG 15]



[FIG 16]



[FIG 17]



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[Subject Code (Reference)]
3K072
5H006
5H007

[F Term (Reference)]
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5H006 AA02 BB01 BB08 CA02 CA07 CA12 CA13 CB01 CC02 DA02 DA04 DC02 GA01
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